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A Turn-key System for fMRI Quarterly Report, Period Ending 31 March 1997

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The development of the Plexiglas headholder device has continued. We have built our third prototype of the unit and have just begun testing its functionality. The initial uses of the unit in actual functional magnetic imaging (fMRI) subject runs has demonstrated some minor engineering problems associated with the lock-down mechanism to the MRI gurney table. Additionally there is a slight tendency of the Plexiglas to flex beyond our tolerances with a human subject located in the unit and forcibly attempting to move. The lock-down mechanism problem has been quickly overcome with a design modification. The Plexiglas flexion problem will be addressed by two methods: 1) using 1" thick Plexiglas for the head support yoke assembly rather than the ¾" thickness used in the present model. Also, the lower neck region of this support yoke where it mates with the base support will be increased in width to provide more structural support in this region, which seems to be the greatest source of the flexion; 2) we also will build the same yoke support assembly from stronger stock material of a different substance, most likely Delrin or nylon. The addition of a mechanism to provide vertical and longitudinal translation of the bitebar along with rotation around its pitch (lateral) axis has provided tremendous flexibility in its comfort level and ease of adjustment/insertion of the subjects into the magnet bore. The base design of the prototype is well within our expectations, and with the improvements to this prototype we are working on at present, we will be ready to go into production by June 1.

Data of the actual movement extremes and average movement during a subject run using our production model will be collected and the resulting analysis reported in our next quarterly report.

The button response box has been in use in our research runs since last November. Production for distribution can begin at any time. We are currently modifying the response box circuitry to expand the number of switches from 8 to 10. This is an upgrade and will not affect production; it will only make the model more versatile. Additionally, we have designed and built a crude layout model of a hand mounted button response mechanism which is shaped to fit a human hand (both left or right hand versions). This is an ergonomic design which should prove much more comfortable and lightweight than the response box. It will not replace the button box, but instead will be available as an optional or additional component. It will be developed into a functional prototype over the next couple of months.

Numerous studies and experiments on the problem of routing signals into and out of the MRI magnet room without encountering significant noise contamination have been conducted. Since Phase I we have demonstrated the capability of being able to transfer signals with no significant noise utilizing properly shielded and trapped circuitry between the control room and magnet room. We no longer rely on optical isolation to achieve noise-free signal transmission. Band-block LC filter traps have been incorporated into the cabling routing signals into and out of the room to trap the spurious noise signals for both RF frequency ranges utilized here (i.e., shielding/trapping for both the 1.5T and 3T magnets). The initial design consisted of a cabling loop to create the inductor along with a capacitor wired into the loop to provide the necessary capacitance. We then designed and successfully tested a simple low volume printed circuit board design that eliminates the bulky wire loop and also prevents destruction of the trapping capability which happens if the shape of the loop is accidentally compressed from its normal circular configuration. This board will be supplied inside a casing with DB-25 electrical connectors to minimize cabling hookup problems and provide for easier handling and storage. Once these units are completed (design is at our local PC board manufacturer for production build) we will run a

series of test configurations again to establish absolute values of our signal mean, standard deviation, and signal-to-noise ratio for specification purposes.

To address a concern we have over the effectiveness of magnetic shielding which should keep the magnetic field in the control rooms of MRI scanners to below 0.5 gauss (according to the MRI engineers), we have obtained a gaussmeter and will be mapping the actual magnetic field in the control room environment of both the 1.5T and 3T magnets. It is possible that other facilities may not have the same high level of shielding that our MRI facilities have.

The prototype for the virtual reality glasses is nearly completed and will be tested late April or early May. The previous planned use of the glasses last fall focused around mounting the glasses at an electrically safe distance from the magnet bore and channel the image of the LCD display screens to the subject via appropriate long optics. We have since demonstrated that the LCD display panels and fluorescent screens can be separated from the printed circuit boards which could not be placed in the magnetic field. We tested the LCD/fluorescent screen assembly without power in the magnet bore immediately above the RF head coil and found no significant level of interference. This means we can mount the LCD panels in direct line-of-sight above the subject if we wish. However, we still prefer to provide an optics system to permit magnification and orientation of the image for better viewing, so the first prototype will consist of the LCD displays with the fluorescent screen lighting panels mounted perpendicular to the subject's face and reflected to the eyes via a transflective mirror which then reflects the image off a convex transflective mirror which magnifies the image to fill the eyepiece. This assembly is part of the manufacturer's eyeglasses as purchased, and has been modified and remounted to accommodate our environment while still maintaining a low volume and a low profile. It has been necessary to construct an interface to extend the cabling (0.5 mm 16 conductor ribbon) to a significant length outside the magnet bore. The manufacturer of the glasses was to provide us with short lengths of cabling for this purpose, but failed to come through. We made our own extensions and are awaiting the prototype PC board for the connection interface from our local board manufacturer at present. The power-on test of the VR glasses in the magnet bore is scheduled for early May. We are investigating mu-metals for enclosing the video matrix driver electronics inside to shield from the magnetic field, as the distance we can effectively extend the VR glasses is only about 10-15 feet.

Electrostatic headphones were obtained from Koss electronics to be tested in the magnet bore as a means for auditory stimulation/distraction as well as providing the audio source for noise cancellation experiments. The headphones were supposedly free of magnetic materials according to a Koss engineer we spoke with, but in reality contained several ounces of lightweight protective steel plates and screws which we discovered after placing the headphones in the magnet bore. The magnetic materials have since been removed completely, the headphones remain totally functional outside the bore, and will be tested along with the virtual reality glasses in early May.

Noise cancellation studies have not begun this quarter. We have discussed the approach and reviewed current noise cancellation techniques on the market. We will plan on a first attempt using a simple inverted audio signal of the gradient pulse noise in the magnet bore collected via an acceptable microphone and routed to an inverting op-amp which then returns the inverted signal to the Koss headphones. We will be obtaining and testing acceptable microphones and simultaneously recording the audible gradient pulse noise from several different locations and orientations inside the magnet bore in the early May experimental run. These recordings will be digitally recorded on a PC sound board for storage, analysis, and manipulation.

No modifications or additions to paradigm procedures were made during this period.

Software development for the Functional Imaging System (FIS) core routines has been under continual improvement. Our major accomplishment has been to make all our tools consistent in their support of volume-wise data. Previous tools had treated data as a series of slices, but this has become bulky with the prevalence of fast multi-slice imaging and our movement beyond examinations of relatively small cortical regions. From the user's perspective,

this is a huge advantage as well, since there are now many fewer entities to understand. This is one of several uses for the general meta-file format that we developed with colleagues at CMU and Pittsburgh Computing Center.

At the primitive end of our analysis stream, we have generalized our statistical programs to encompass multiple raw file formats, including time-series, per-trial time-series, Analyze time-series, and ANMR echo planar time-series. These C++ classes are quite general and simple, and encompass semantic information about what was happening during a trial as well. This code, in addition to our statistical package, has been modularized to ease future extension with provisions for foreign interfaces such as MATLAB. We continue to extend our viewing program to provide the investigator with more powerful ways to view results. We've recently generalized the internal coordinate handling of this package so that data can be viewed in any orientation, and overlaid on anatomicals from any source or orientation.

Calculations on the computing capability of new computer CPU's have indicated we should be able to perform real-time or near real-time data reconstruction using 200 MHz PentiumPro CPU's. At present this takes ~12-14 hours on our HP 735 computer system. We have purchased a dual 200 MHz PentiumPro computer with adequate RAM and hard drive storage to attack the real-time processing problem. Utilization of the multi-processor environment should make this achievable at good image resolution. We have also purchased a CD ROM read/write device to investigate its hardiness as a data back-up system for the large amounts of data files generated in a subject run and analysis.

We have just begun the development of the GUI interface to provide reasonably user friendly interaction with the core FIS software routines. This interface is being written in the Java programming language to provide multi-platform capability to our software package. This will enable us to run under not only our standard Linux (UNIX) environment, but Windows 95/NT and Macintosh environments as well in the future. It will also allow users to add/modify routines to meet their needs. Our persistent data storage will now be under a database structure (at present we are considering a relational database known as mini-SQL, but have not locked in to it). This is a move from the flat file structure we have been using to this point. The Help routines will be written in HTML browser format to make it easy to use and easy to write and modify. Tutorial and Wizard software will also be developed over the spring and early summer.